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EFFECTS OF LONG-PERIOD SOLAR ACTIVITY FLUCTUATION ON TEMPERATURE AND PRESSURE OF THE TERRESTRIAL ATMOSPHERE

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16. Abstract

Reviews the present state of research of the influence of the 11-year solar cycle on climatic conditions in the troposphere, including a short historical treatment.

Gives a short history and reviews the present state of research on the influence of solar sunspot activity on tropospheric temperature and pressure. Affirms the existence of an 11-year temperature cycle of 5 different types and criticizes denials. Similarly affirms a cyclic change in atmospheric pressure, deducing characteristic changes between 11-year cycles. Establishes the existence of 80-year and 5-to-6-year cycles of temperature and suggests physical causes for both. (A74-37698)

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EFFECTS OF LONG-PERIOD SOLAR ACTIVITY FLUCTUATION ON TEMPERATURE AND PRESSURE OF THE TERRESTRIAL ATMOSPHERE

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The problem of solar effects on the troposphere began as a topic of genuine scientific investigation with the classic study of Köppen (1873 [30]), where it was shown that the air temperature in tropic latitudes followed an 11-year cycle with an amplitude of about 0.5°C., and that the highest temperatures occurred during periods of minimal solar activity, the lowest, during solar maxima. We should note that already in this article the periods of temperature extrema were found not to coincide exactly with periods of extrema in solar activity; rather, the lowest temperatures were observed some time after maxima in the 11-year solar cycle, while the highest temperatures lagged behind the corresponding minima. As is well known, this fact allowed Köppen to extend the annual variation he had discovered to temperature at temperate latitudes with respect to periods of solar activity. /43*

It is also well known that the question of the distribution of temperature by phase of the solar cycle was first examined on a global scale by Clayton [24] and Walker [46]. Properly speaking, Clayton did not extend his examination over the entire phase but studied only the differences of distribution at maximal and minimal periods of solar activity. He compared the average annual values of atmospheric temperature at maximal periods (the year of maximum activity ±2 years) and minimal periods (year of the minimum ±2 years) for the five 11-year cycles, Nos. 11-15. The general amplitude was about 0.5°C., which agreed with the result obtained by Köppen.

* Numbers in the margin indicate pagination in the foreign text.

The problem of temperature distribution within the 11-year cycle led immediately to the study of regional seasonal anomalies in temperature. A great deal of research was conducted on this topic, among which the excellent work of Köppen, "The Law of Recurrence of Severe Winters in Western Europe," stands in the forefront. In it he showed that two severe winters occurred in practically every observed 11-year cycle. Nordmann [36] also conducted research on the distribution of temperature at different points on the earth within the 11-year cycle at the beginning of this century. A series of studies were later published by German researchers. Dostal [25] applied a method of autocorrelation to the Berlin temperature series for 1769-1930. He did not obtain the continuous 11-year waves, but a spectral analysis of the Wolf numbers and the Berlin temperature provided a completely satisfactory agreement at the second harmonic (4-8 and 13 years). /44

Fisher [28] established that unusually warm Julys in Frankfort-am-Main occurred predominantly during years of extreme solar activity. [In contradiction to Köppen's tropical result--transl.]

Meissner [33] found that, with some exceptions, all the maxima in the 11-year cycles during 1831-1935 corresponded to below-average annual temperatures in Leipzig. For periods of minimal solar activity, however, he found no unusual temperature correlation.

Veksler [4] performed an investigation of the distribution of atmospheric pressure and temperature during the course of the 11-year cycle in greater detail than any previous author: he used material for 1899-1939, that is, for a somewhat later time period than that which was the basis of Clayton's work. One feature of Veksler's work was that he apparently for the first time oriented the results not by the actual locations of the stations but by a coördinate network (of intersecting latitudes and longitudes). This method has subsequently become the general practice. Another special feature was his distinct examinations of the summer and winter seasons. From the data of four cycles of solar activity, Veksler constructed curves of the distribution by latitude of the differences in atmospheric pressure between periods of solar maximum and minimum. The most striking difference was at moderately high latitude (55-70°), where the pressure during solar maxima exceeded that during the minima (a "positive" pressure difference). At about 45° latitude, and again at about 20°, the differences decreased to zero. Between latitudes of 45° and 25°, the pressure difference was negative.

Veksler's work also dealt with the period 1950-1951, that is, included already the most recent period in the research of solar-tropospheric relations. He analyzed pressure differences between periods of maxima and minima in the solar cycle not only by latitude, but also in their distribution over the globe generally. In general, he confirmed the accentuation law given above.

Veksler established the existence of positive differences above the Aleutian Islands, Greenland and north central Siberia, while negative ones were located above Hudson's Bay, southern Scandinavia, and the neighborhood of Yakutsk. Thus, he already observed some deviation from the "classic" accentuation law, according to which, positive differences, in addition to Greenland, should also be observed above the Azores and probably shifted toward Mongolia in Siberia (in the corresponding season, it goes without saying, but Veksler once observed it in January). /45
As for the negative differences, they should have been observed, not only above the Aleutians, but also above the Netherlands,

where, in actuality, one of their centers was shifted to southern Scandinavia.

These deviations from the initial accentuation law are clearly due to the fact that Veksler combined the data of two cyclic epochs, from 1899 to 1919 and from 1919 to 1939, which one may not do, as L. A. Vitels [5] has shown.

Schindler [39] investigated the Prague temperature series with the aim of determining at which phase of the 11-year cycle an anomalous season occurs. For example, a cold summer was observed most often in Prague during the year before solar maximum, and a warm winter three years after a maximum. This relates, however, to the height of a cycle; that is, in addition to the 11-year cycle, there is cyclic behavior of a higher rank [position on a scale of frequency - transl.]. To introduce the corresponding comparisons for the higher cycle; on the average, for example, cold summers occur in years of maxima; but in the lower cycle again, in the years preceding the maxima. In addition, two extrema are occasionally observed within one 11-year cycle; that is, there is a 5 to 6-year cycle. For example, very warm winters occur in the higher cycle in years prior to the minimum and in years two years after the maximum. The four gradations of type of season over three gradations of height of cycle, however, lead to the conclusion that a limited sixteenth of the 11-year cycle over long series does not have a sufficient reliability. He did not succeed in establishing connections for the remaining two seasons of the year.

Voigts [45], using Bauer indices (random differences - relative to the maximal period - in the value of the average annual area covered by sunspots and faculae), found five types of behavior in the average annual temperature in the 11-year cycle:

1) Polar: following a 5-6-year cycle;

2) Mediterranean: also following a 5-6-year cycle;

3) Atlantic: a maximum temperature two years prior to the solar activity minimum, and a temperature minimum 2-3 years after the maximum in the solar cycle;

4) Central European (actually also dominant in large parts of the USA): a maximum temperature 2-3 years after the year of the minimum in the solar cycle, and a minimum temperature 1-3 years prior to the maximum in the cycle;

5) Tropical: temperature maximum coincident with a minimum in the solar cycle, and vice versa.

The experimental reconstruction of the temperature conditions of 1816 can serve as confirmation of the hypothesis that at the low 11-year cycle, the cyclical maximum coincides with or is very slightly displaced from years of cold summers (see the work of Schindler [39] mentioned above), and it is all the /46
more interesting, since it coincides with the period of the maximum of the low 11-year cycle. Such a reconstruction was carried out by Hoyt [29], who showed that it was actually a cold and dry summer in the northeastern states of the USA as well as in Europe. Hoyt, to be sure, regarded the increase of volcanic eruptions during the years 1812-1816 to be the cause of this anomalously cold summer.

Trenkle [43] established that there were 27 years from 1850 to 1956 in which the Wolf numbers from July to November increased by no less than 5 units. The winters in 25 of these 27 years were warmer than usual in Central Europe.

The work of T. V. Pokrovsk compared temperature anomalies with the phases of the solar cycle. The method used in the work can be considered a sort of single-factor dispersion analysis. It examined the value of the sign of the phase throughout the

11-year cycle (the entire cycle is divided into the four well-known phases).

In some cases this sign appears to be essential. In some ways, however, the conclusions of this work lead to arguments which support a 5-6-year cycle.

In the classic monograph of E. S. Rubinshtein and A. G. Polozova, there is a chapter, "Cyclic Oscillation of Air Temperature," devoted to the relation between temperature behavior and solar activity. It is interesting that the authors established distinct connections for the 11-year cycles No. 11 through 20, for the high phase, that is, of the "old" cycles - just the phase, during which certain other relations of the solar activity to processes in the troposphere were disturbed. We should note that an 11-year cycle was indicated by no means for all the stations used by the monograph authors, only for 10% of the stations, and it was not even indicated for all the months of the year.

Finally, a few words are in order concerning the recently published work of Trepinska [44]. Studying the Cracow temperature series for 1826-1965 and applying harmonic analysis, Trepinska established a periodicity very close to 11 years.

During the last decades there has been no shortage of critical works whose authors have refuted the figure of an 11-year cyclical recurrence in atmospheric temperature. Stranz [42], for example, analyzing the temperature series for 100-130 years of the cities of Berlin, Stockholm, and New Haven Conn. (USA), came to the conclusion that the differences of the average temperature in periods of maxima and minima in the 11-year cycle lay within the limits of error (on 36 occasions).

Shaw [41] conducted a frequency-spectrum analysis on the temperature series of New York City, a Dutch station, and a station in central England (this last was the most extended in time of the three series - 258 years; the homogeneity of such a series is somewhat doubtful). The analysis showed that the only significant periodicity was the 12-month harmonic. Shaw did not detect any trace of an 11-year or any other cyclic /47
recurrence which would support a connection to solar activity.

Shaw's results were criticized in turn by Mitchell and Landsberg [35]. They were critical of Shaw's use of a method of preliminary averaging of the data. Generally speaking, series often need to be averaged before frequency spectrum analysis can be applied. But this smoothing must be carried out correctly, which implies a proper choice of operator, a proper weighting function, and so on. Shaw did not concern himself with this, obtained a trivial result, and assumed that he had finished the problem of relations between solar activity and terrestrial temperatures.

Norton [37] worked on the average monthly temperatures in Greenwich from 1764 to 1862 and did not find evidence of an 11-year cycle. Critics compared his method to that of Shaw.

Let us summarize the results of contemporary research on the effect of the 11-year cycle of solar activity on atmospheric temperature.

1. First of all, investigation has confirmed that the 11-year cycle is manifested differently in different geographic areas. There are regions where no effects are generally felt, indeed, according to Rubinshtein and Polozova, such regions are in the majority.

2. The appearance of the phases of the 11-year cycle in air temperature is different for different months of the year at the same geographic point. Frequently, the effect may be different at two points relatively close to one another in the same month of the year. There is a general tendency toward negative temperature anomalies in the northern periphery of temperate latitudes during the winter months in periods of maxima in the solar activity.

3. The values of the anomalies are not generally large (0.5-1.0°C.), and they only become large at certain geographic points.

4. The sign and the value of the anomaly depend in large measure on the height of the 11-year cycle, that is, seem to be related to the phase of the "ancient," that is, secular, cycle.

With respect to pressure, the excellent and well-known work of Vitels [5] on this problem was very important; although the major conclusions concerned the secular cycle, his research is of considerable interest with respect to the 11-year cycle. This work showed for the first time how changes in the law of accentuation of barometric pressure proceeded with the growth of the secular cycle.

Breier [22] found that during periods of maxima in the 11-year cycle, the polar anticyclone was much stronger than in periods of minima. He examined the period from 1899 to 1939 for periods of maxima (±1 year) and minima (±1 year). At high latitudes the difference in pressure was positive and during the winter (September-March) consisted of 1 millibar, during the summer (May-September), of 0.5 millibar. Between latitudes 50° to 20° N., the difference was negative and consisted of about 0.1 millibar during the winter, somewhat more during the summer. The greatest increases in pressure during the winter in periods of maxima in the 11-year cycle occurred above Greenland, the Aleutian Islands and northern Siberia. /48

Faust [27], starting from the ideas of Bauer, proposed that with an increase of solar activity, there is a tendency toward weakening of the east-west transport of air and toward the formation of stable anticyclonic circulation.

Tests of the effectiveness of the law of accentuation of barometric fields drew more attention. It appears that Vitels also approached this problem correctly, explaining the changes of the character of this law as a transition to a new circulatory epoch. Vitels clearly insisted on the necessity of examining separately the circulatory epochs 1900-1919 and 1920-1939. When data existed that a new circulatory epoch began, say, in 1910, those researching this question had to regard the new epoch separately. Obviously, the character of the law of accentuation changes from epoch to epoch just as the character of solar-terrestrial relations changes with time in general.

On the basis of the indices of the barometric and circulatory behavior constructed by Vitels for the European synoptic region from 1900 to 1965, A. I. Ol' [12] constructed cyclical curves of the number of days with profound cyclonic circulation and powerful anticyclonic circulation both, separately for each of eight subregions, combining all seasons together, and for each season, combining all subregions together. Applying the criterion of advancing time, Ol' came to the conclusion that increasingly constant connections in the barometric and circulatory indices under examination led to an increase in the anticyclonic circulation two years after the maxima in the 11-year cycle. This regularity was expressed most often during the spring season in the Western European region. Ol' concluded that even in the best case, the law of accentuation of the barometric field was only a characteristic tendency.

I. B. Maksimov and B. A. Sleptsov-Shevlevich [11] studied the average annual values of the atmospheric pressure at various locations in the northern hemisphere during the 12th through the 17th cycles of solar activity. They treated the data on pressure by the method of harmonic analysis. From a map of the amplitudes and phases, they concluded that there was an absence of standing waves of pressure in the 11-year cycle, and the waves indeed appeared to be moved. Proceeding from this, they also drew the conclusion that the law of accentuation was insufficient.

Summing up the results of the study of the variation of atmospheric pressure during the 11-year cycle, it is quite noticeable that most of the attention has been paid to the law of the accentuation of the barometric field. In this connection, Vitels obviously assumed the correct viewpoint: the law of the accentuation of the barometric field changes its character with the change in phase over many years of the solar activity. We probably have the same situation with other solar-tropospheric relations, as well: effective in one epoch, they are then disturbed, and sometimes even begin to work in a contrary direction. /49 In such cases we cannot approve the urge to obtain the longest possible series, which then requires extensive mathematical treatment and statistics, and to ignore the mixing of different circulatory epochs. The indefinite conclusions which certain authors have obtained as a result follow from their careless collection of material. True, the confusion of different circulatory epochs is sometimes required to maintain the precision of the statistical method of approach, but the physical precision always suffers in this method of approach.

In a period of a low secular level of solar activity and at the beginning of its growth phase, the law of accentuation of atmospheric pressures by the 11-year cycle reflects an increase in the intensity of atmospheric circulation without essential change of its character, although its reconstruction is also proceeding (as was shown in turn by A. Ya. Bezrukova [1]). Further effects of the accentuation produce, in addition to the strengthening of the stationary anticyclonic circulation, a more-or-less powerful opposing anticyclone (often rather distant from the location of the stationary maximum). Atmospheric criculation is shifted from the generally zonal to the meridian. The law of accentuation, as we are accustomed to represent it, no longer exists, although it is maintained in an altered form. Despite this, it indubitably does exist, and it has not been detected in recent investigation only because the authors have mixed together different circulatory epochs.

Ol' devoted a review article [13] published three years ago to the effect of a 22-year cycle of solar activity on climatic characteristics. Prior to the time of appearance of this article, no especially essential results had been obtained in this regard.

During previous decades, a large literature has been devoted to the effects of the so-called secular cycle of solar activity on meteorological phenomena.

Perhaps the first more-or-less consistent expression of support for the existence of a secular cycle in meteorological phenomena belongs to Memery [34] (at the end of the '20s of this century) and to Schmauss [40] (in the '30s). At that time the period of the cycle was assumed to be a century. On the basis of catalogs of European dry winters assembled by Easton [26], Köppen [31], and, in a more continuous form, by Scherhag

[38], it was established that the period of the cycle was close to 90 years. Scherhag and Wisser [48] even spoke of a period of 89 years.

The discovery of an effect on the climate of an 80-90-year cycle of solar activity had great theoretical significance, since it helped to establish a mechanism of the effect of solar activity on climate. At about this time research began on secular cycles in the troposphere.

In a 1939 work [18], Angström noted that a gradual increase of winter temperatures was connected with a strengthening of the atmospheric circulation. This mechanism operates, in Angström's opinion, in climatic oscillations of different duration.

Landsberg in 1943 [32] investigated the 168-year temperature series for the city of New Haven. He used the index /50

$$T_i = 100(\overline{T}_X - \overline{T}_{IV})/R$$

where $\overline{T}_X$, $\overline{T}_{IV}$ and R indicate respectively the average October temperature, the average April temperature, and the annual amplitude of temperature change. Forming a 30-year moving average, Landsberg detected a growth in T_i during the period 1810-1948 with a simultaneous fall in R. Landsberg agreed with Angström to the effect that only one moving average was insufficient to show climatic oscillation and that a stronger statistical criterion was necessary as well as the use of the distribution of annual amplitude. The evaluation of the differences between the October and April temperatures shows that the oscillation of differences is perfectly real.

I. V. Maksimov [10], on the basis of secular oscillations in the ice thickness near Iceland in 1590-1930, the average levels of the Caspian Sea from 1790 to 1940, and the recurrence of dry winters in Western Europe, showed that the duration of the climatic cycle was equal to 77.3 years with an amplitude approximately 50% of the complete amplitude of climatic oscillation (the rest is taken up by other cycles). He determined that about 1894 there was a maximum continentality in the climate and a maximum in the ice thickness in the North Atlantic. Around 1934 conditions were the opposite. The 80-year cycle was distinctly revealed by study of periods at the end of the century (we note that Maksimov also found a 600-year cycle almost simultaneously in the same data).

Willet in 1951 [47] conducted extensive research on the effect of a secular cycle in the troposphere. Willet established what he considered typical variations in climatic characteristics for the corresponding phases of the secular cycle. Having studied a great deal of material, Willet found that the first quarter of the 90-to-90-year cycle was characterized by the development of zonal circulation gradually extending to the polar region; at the boundary between the third and the fourth quarters, conditions formed which were favorable for the formation of the blocking anticyclone. The fourth quarter of the cycle is characterized by the formation of a blocking anticyclone.

Krapfenbauer in 1960 pointed to the existence of a 79-year cycle which turns out to trace back according to different sorts of journalistic data clear to the 14th Century. The ascending branches of the Krapfenbauer cycles are short, between 20 and 30 years, and the descending ones, approximately 50-60 years. There were minima in the cycles of 1670, 1750, 1810 and 1910, and maxima occurred in 1690, 1780 and 1850. Consequently, at the end of the present century we can expect a minimum: it is possible that we are very close to a minimum in the present cycle right now. If we take into account the result that in this century the basic period of Arctic heating occurred between 1915 and 1938 (L. S. Berg [2]), then Krapfenbauer's argument, that the ascending branch of the climatic oscillation is shorter than the descending branch, finds confirmation.

Finally, in the already-mentioned recent article [44] of Trepinska, which we referred to with respect to the 11-year cycle, there was observed a striking 90-year cycle in the Cracow temperature series, and its amplitude was larger than the amplitude of the 11-year cycle. /51

The indubitable existence of an 80-to-90-year solar cycle in the climate brings up the question: if its amplitude is greater than the amplitude of the 11-year cycle of climatic change, how is the amplitude of the accompanying solar cycle less than that of the 11-year solar cycle? In the actual example of the 19th Century when, as in the present century, the effect of the "supersecular" (that is, the 600-year) was not so strongly observed, the lowest point in the cycle had a maximum of 46 units of Wolf numbers (1816) and the highest 137 units (1837), that is, the ratio is equal to 3. At the same time, the height of the maximum average of the 11-year cycle was 100 Wolf number units and the minimum, 5 units. In other words, the second rationis 20, some 7 times greater than the first ratio. There is no doubt that the more significant effectiveness of the 90-to-90-year cycle of climatic oscillation compared to the 11-year cycle is explained first of all by its duration. The time factor, if it be represented as a factor, appears at a higher power than in the first, perhaps as the square. This must be fully understood if we are to account for "self-acting" climatic oscillation of which Burke writes [23] concerning the breakup of Arctic ice.

But there is an alternate explanation. The fact is that the 80-to-90-year cycle is distinct from the 11-year one not only quantitatively, but also in a qualitative way. It is well-known that the number of long-lasting (and therefore large) groups of sunspots follow the same 80-to-90-year cycle. It may well be imagined that the special effectiveness of the secular cycle is also explained by its qualitative peculiarities. The question of the relative weight of purely climatic and solar factors cannot be decisively resolved. For this it will be necessary to develop a theory of climatic oscillation which can account in a finite calculation for the amount contributed by the purely geographic factor in the effect of the secular cycle.

We noted some time ago that a whole series of tropospheric phenomena, in contradiction to, say, the ionospheric and geomagnetic ones (excluding cases of the geomagnetic index K_p treated by the proper methods) produce not one, but two, maxima in the course of an 11-year cycle. The importance of this question was understood by Baur, who discerned a double wave in the macrosynoptic situation in the course of one 11-year cycle. In 1949, Baur investigated this question, showing by means of a measurement of the χ^2 index that the double cycle was real [19]. Baur came to the conclusion that an increase in the zonal circulation, the intrusion of the subtropical belt of high pressure into the higher latitudes, and the simultaneous growth in the barometric gradient from the equator to the pole, all took place two years prior to the extrema of the 11-year cycle. A weakening of the zonal circulation and an increase in the Mousson factor is observed in years of extrema /52
in the 11-year cycle.

However strongly the work of Baur persuades from the meteorological viewpoint, it is weak from the astrophysical viewpoint when Baur tries to explain the macrometeorological appearance of oscillation in the solar constant as caused by the cumulative activity of sunspots and faculae. In order to obtain the requisite value of oscillation, Bauer has to admit that the temperature of faculae must be 2000-4000°C. above the temperature of the photosphere, a supposition which cannot withstand astrophysical criticism.

In a pair of works published in 1959 [21, 22], Bauer totally denied the presence of an 11-year cycle of large-scale meteorological phenomena, particularly at temperate latitudes, and insisted on a double wave of large-scale weather within the limits of each 11-year solar cycle. In addition, Bauer claimed that the second summer after a maximum in the solar activity was an arid one in Central Europe. It is of note that in this work, Bauer does not mention solar radiation in general, but speaks only of its active components, the double oscillation of which within the limits of each 11-year cycle has a greater probability.

From that year there has been no shortage of research on the existence of a 5-to-6-year cycle in a series of tropospheric phenomena. In almost all the phenomena of the lower levels of the terrestrial atmosphere and in some hydrospheric ones, if the action of solar activity is observed in them in general, it is now affected by a double wave within the limits of each 11-year cycle. A whole series of works which have been mentioned here with respect to the 11-year cycle also make note of the existence of a 5-to-6-year cycle: this concerns the work of Wisser, Voigts, Pokrovskaya, Landsberg, Schindler, work conducted under the leadership of Yu. B. Khrabrov [3], and others.

How much data exists to confirm that this cycle is of solar origin? Bauer's reasoning on the cause of oscillation in the solar radiation within the limits of the 11-year cycle hardly merits attention. Now the different sorts of rhythms and cycles on the sun may have either a physical or a geometric nature. Zhukov and Predtechenskii have felicitously termed the rhythms of a physical nature rhythms of state, and those conditioned by the mutual distribution of the sun and the earth, rhythms of position [15].

Let us consider whether the 5-to-6-year cycle can be treated as a type of rhythm of state. Eigenson [17] has shown that the index reaches a maximum value twice in the 11-year cycle. For a variety of reasons, however, this result cannot be considered entirely convincing. It is possible to be more definite about a double wave in the solar activity on the basis of the research of M. N. Gnevyshev [6], who (admittedly with material limited by the duration of extraterrestrial observation of the solar corona) observed two maxima in the brightness of the spectral line 5303 Å in the course of one 11-year cycle. We cannot deny, then, that the 5-to-6-year cycle in meteorological phenomena may reflect some solar rhythm of state. /53

The rapidity of changes in solar activity also supports the influence of a rhythm of state of the sun on the troposphere. It is clear, if we speak of the average annual values, that the rapidity of change reaches a maximum value two times in the course of the 11-year cycle. The first is a maximum of the positive value of the derivative of the Wolf numbers with respect to time, that is, the first differences of the annual values, and the second is a maximum of the negative values of the derivative. The mechanism of action of such changes on the troposphere is not known, just as the general mechanism of solar action on the troposphere is unknown, but in principle such influence is not excluded. Despite the correct criticism of the recent monographs of I. P. Druzhinin and his coworkers [8, 9], we cannot conclude that this collection of material proves nothing and implies nothing. Such a situation would be highly unlikely.

A rhythm of position as a possible explanation of the nature of the 5-to-6-year cycle in the troposphere could be the change of the zone of latitude of the basic activity of the sun in the course of the 11-year cycle (the Sperer law). In periods of maxima, the activity is at its greatest, but the latitude zone of the activity is not that which is most favor-ably placed to affect the earth. On the descending branch of the cycle, the activity is centered on the heliographic latitude in which activity may produce the greatest terrestrial effect.

It is finally not to be excluded that the 5-to-6-year cycle represents an autonomous formation of the 11-year cycle in the lower troposphere: the layer of the terrestrial atmosphere could be responsible for the double wave on the basic 11-year cycle. Following upethe results obtained by A. A. Dmitriev [7] with respect to the effect of solar activity on the coefficient of vertical turbulence and on the coefficient of macroscopic horizontal turbulence exchange, and recalling as well that the value of this exchange is defined not only by the above-mentioned coefficient, but also by the temperature limits along the meridian, one can construct a qualitative model which produces a 5-to-6-year cycle in the reaction of the lower atmosphere to solar activity.

These are the apparent possible explanations of the 5-to-6-year cycle. We will not dwell on other intrcyclic (in the sense of the 11-year cycle) oscillations of tropospheric characteristics which some have considered portions of the 11-year cycle (such as the 2-year, which is most probably a comparatively high-frequency harmonic of the solar activity cycle, the 3-to-4-year oscillation of atmospheric pressure above India, the 4-year cycle in the temperature of Budapest, or the 7-year temperature cycle frequently observed at a variety of locations).

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